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Indian Standard

GUIDE FOR TESTING OF
PHYSICAL CONDITIONS IN COLD STORES

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GUIDE FOR TESTING OF PHYSICAL CONDITIONS IN COLD STORES

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Indian Standard

GUIDE FOR TESTING OF PHYSICAL CONDITIONS IN COLD STORES

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 3 January 1974, after the draft finalized by the Fruits and Vegetables Sectional Committee had been approved by the Agricultural and Food Products Division Council.

0.2 The objective of this Indian Standard is to introduce uniform terminology to industrial cold storage practices in this country. Further, the standard incorporates the most suitable methods for measuring the physical conditions inside cold stores, thereby helping cold store operators to interpret correctly and apply uniformly the provisions of a series of standard guides which ISI has issued on cold storage of fruits and vegetables.

0.3 In the preparation of this standard assistance has been derived from the ISO draft proposal on the subject.

1. SCOPE

1.1 This standard prescribes definitions of the most commonly occurring terms in industrial cold storage practices of fruits and vegetables. It also includes methods for measuring the physical conditions inside cold stores.

2. TEMPERATURE

2.1 Temperatures to be Considered

2.1.1 *Temperatures Applied to the Products* — For the cold storage of a product of plant origin, many temperatures or ranges of temperature have to be considered, namely:

- a) *Lethal temperature* — That temperature which causes freezing of the tissues.

- b) *Critical temperature* — The temperature in relation to a given storage period and a particular fruit or vegetable above or below which there occurs either:
 - 1) Physiological disorders, such as, browning at low temperature or textural modifications of the tissues. (*Examples*: cucumber, banana, internal browning of avocados or lemons, etc); or
 - 2) Inability to obtain normal ripening after storage.
- c) *Optimum long-term storage temperature* — The temperature which enables satisfactory long-term storage.

2.1.2 In industrial cold storage practice sufficient safety margin should be kept to account for unavoidable fluctuations in the temperature inside the cold store. Therefore, the optimum long-term storage temperature for a particular product should be either the lethal temperature plus safety margin, or the critical temperature plus safety margin.

NOTE 1 — The damage at a given temperature depends on its period of application.

NOTE 2 — In the case of short-term storage, it may be possible to keep certain produce at the critical temperature or at a temperature below this without causing physiological disorders.

NOTE 3 — For long-term keeping, the temperature of the product should always be above the lethal temperature and, whenever necessary, above the critical temperature.

NOTE 4 — However, for certain fruits, such as Williams pears, the critical temperature may be above the optimum refrigeration temperature.

2.1.3 *Temperatures of the Atmosphere in the Cold Store*

2.1.3.1 *Temperature at a point* — The temperature measured at a well-defined point inside the cold store.

2.1.3.2 *Practical mean temperature* — The different temperatures of the atmosphere in a cold store fall between upper and lower limits.

2.1.3.3 The practical mean temperature of the atmosphere in the cold store, in a period of temperature equilibrium, is the arithmetic mean of the maximum and minimum temperatures.

NOTE — Strictly speaking, the mean temperature of the cold store is not equal to the arithmetic mean of the maximum and minimum temperatures, but the arithmetic mean should be considered sufficiently close to be used in industrial storage. The actual temperature of the product will depend essentially on that of the surrounding atmosphere.

2.2 Cold Points and Hot Points in a Refrigerated Enclosure

2.2.1 *Cold Points* — Points where the temperature of the atmosphere is at the minimum.

NOTE — In a store provided with fans, the cold points are most often in the zone near the evaporator where air leaves the cooler.

2.2.2 Hot Points — Points where the temperature of the atmosphere is at the maximum.

NOTE — The hot points are not always accessible and their measurement is often difficult, if not impossible.

2.3 Choice of Atmospheric Temperature in the Refrigerated Enclosure — It is recommended that, at the cold points inside the cold store, the temperature should be equal to or slightly above the optimum keeping temperature of the product.

2.4 Measurement of Temperature — Temperatures may be measured continuously or intermittently.

2.4.1 Continuous Measurement — Continuous measurement of the temperature may be done either by direct reading or by recording.

2.4.2 Intermittent Measurement — Intermittent measurements are:

- a) Periodic check measurements when recording instruments are not available,
- b) Supplementary measurements,
- c) Verification or standardization of thermometers.

2.4.3 Instruments for Temperature Measurement — The instruments used at present are:

- a) Mercury or alcohol thermometers;
- b) Portable recording thermometers, using a bimetal strip with lever transmission;
- c) Distant-reading thermometer based on vapour pressure or liquid expansion, either direct-reading or recording; and
- d) Resistance thermometers, thermistors or thermocouples, direct-reading or recording.

2.4.4 Standardization of Thermometers — Standardization of thermometers is an essential operation which requires great care. Standardization should be carried out periodically within the temperature range and the conditions of use. It should be done during a period when the operation of the refrigeration plant is stable. The inertia of the sensitive elements of the thermometers is less in moving air than in still air or in slowly circulating air. It is recommended that thermometers should be standardized in moving air.

In industrial storage practice, standardization can be done with mercury thermometers in annealed glass, provided with a certificate from an approved organization.

It is recommended that the standard mercury thermometer should be placed in a fixed position, at the cold point of a ventilation circuit, behind glass and near to the temperature-sensing element of a distant-reading thermometer.

In every case, it is desirable to protect the bulb of the standard thermometer from any external thermal radiation (human body, source of illumination, etc).

2.4.5 Measurement Points

2.4.5.1 Choice of points — The measuring instruments should be placed, preferably, where they will be shielded from condensation, abnormal air movements, radiation, vibration, and possibly shocks. The sensitive elements of the thermometers (sensors) should be placed as far as possible at representative points in the cold store (cold points and hot points when this is possible).

2.4.5.2 Definition of measurement — Each measurement should be defined by the nature of the temperature measured (for example, temperature of the produce concerned, temperature of the atmosphere) and by an indication of the place of measurement. Some recommended points for the measurement of temperature are shown in Fig. 1.

3. RELATIVE HUMIDITY

3.1 General — The measurement of relative humidity is delicate and the accuracy is less than that obtainable with temperature measurements.

The relative humidity of the atmosphere in the cold store depends on many factors, such as:

- a) Nature of the produce and the packages;
- b) Loading of the cold store;
- c) Surface area and the structure of the evaporators, and the surface area and arrangement of the fins;
- d) Difference between the evaporator surface temperature and the practical mean temperature of the atmosphere;
- e) Ventilation system (speed of air circulation and means of distribution of the air in the cold store);
- f) Insulation of the cold store;
- g) Air changes, etc.

As a consequence, the relative humidity can vary with the time and space.

To obtain the recommended high relative humidity (80 to 90 percent) for cold storage, it is necessary to have evaporators with a large heat-exchange surface and to ensure that the difference between the temperature of the refrigerant fluid and that of the atmosphere of the cold store is as small as possible, subject to losses from heat transmission.

In practice a difference of the order of 5°C between the mean temperature of the store and that of the refrigerant fluid can be accepted. Thus, for a cold store controlled between 0° and $+2^{\circ}\text{C}$ and suitable insulated, the evaporation temperature of the fluid should be of the order of -5°C to -3°C .

3.2 Principles of Measurement — In the long-term keeping of fruits and vegetables, the aim is to obtain as constant a relative humidity as possible.

Practically stable relative humidity is attended over a certain period of time, and measurements should be carried out only during a period of time, and measurements should be carried out only during a period in a state of approximate equilibrium.

The state of equilibrium in relative humidity in a cold store may be influenced by:

- a) loading of the store (which may vary considerably, especially at the beginning and end of storage);
- b) the variations in intensity of transpiration of fruit or vegetables. (Transpiration is greater for produce in the process of being cooled);
- c) the dryness of the packages, which represents 15 to 20 percent of the total mass of the product. The packages are made of wood or cardboard, that is of hygroscopic material which can absorb or desorb water at a comparatively rapid rate. If packages which are too dry are put into the store, they will tend to absorb a large percentage of their mass of water to the detriment of the relative humidity of the store. If the packages are too damp the opposite effect will occur.

Therefore, it is necessary to try to determine at what time the state of comparative equilibrium is established, as indicated by limited variations in relative humidity, and it would be desirable to begin measurements of relative humidity as soon as the store has been loaded, so as to show a period of stabilization characterized by variations of small amplitude. It is recommended that any corrections to the relative humidity should be made only after the stabilization period is reached.

3.3 Instruments

3.3.1 Hair Hygrometers — These instruments are of low precision, low sensitivity and low accuracy, especially in the region of high relative humidities (80 to 90 percent) but they are easy to use.

If the relative humidity is high, it is recommended that they should be standardized regularly (once every month, for example) with a psychrometer (standard instrument or whirling psychrometer).

The standardization of hygrometers against a psychrometer under the usual conditions of cold storage is difficult and not very accurate because the difference in temperatures between the dry bulb and wet bulb thermometers is small (for example, 1°C with a relative humidity of 85 percent and dry bulb temperature of $+1^{\circ}\text{C}$).

To obtain favourable conditions for the measurement of relative humidity the following precautions are recommended:

- a) Leave psychrometer and its accessories at the site of measurement for a sufficient period (2 hours for example);
- b) Wet the sleeve of the wet-bulb thermometer with demineralized water;
- c) Read the temperature of the thermometers and of a psychrometer at the moment when a constant difference between the dry-bulb and wet-bulb temperatures has been reached;
- d) Preferably make several measurements at the same place;
- e) Avoid making measurements at the moment when the fans of the refrigerating plant stop or start, if they do not operate continuously.

If a standard psychrometer or a whirling psychrometer is not available a hair hygrometer can be placed in a saturated atmosphere for at least 48 hours and the needle on the scale or the recorder brought to 100 percent. This has the disadvantage of giving only one check point.

3.3.2 Electrical Hygrometers — Electrical probe hygrometers allow measurements to be made at a distance and allow the determination of relative humidity of the microclimates which occur in piles of packages, provided that in every case the temperature of the atmosphere at the point of measurement is accurately determined. Such apparatus is accurate for relative humidities not exceeding 95 percent.

These are hygrometers, the principle of operation of which is based on the relation between the concentration of a sodium chloride solution (measured by electrical conductivity) and the relative humidity of the atmosphere in equilibrium with it.

3.3.3 Psychrometers — Aspiration hygrometers or whirling hygrometers are specially recommended if relative humidity is high.

3.4 Measurement Points — Several recommended points for the measurement of relative humidity are shown in Fig. 1.

4. AIR CIRCULATION

4.0 A distinction should be made between the circulation of the atmosphere which takes place in a closed circuit and the air change which consists in introducing outside air into a cold store.

4.1 Circulation of the Atmosphere

4.1.1 Purpose — Circulation of the atmosphere is intended:

- a) to initiate cooling of the produce on entry into the cold store;
- b) to make uniform the temperature of the produce and to a certain extent the relative humidity in the store; and
- c) to draw from the packages the gases and volatile compounds produced by metabolism of the stored produce.

4.1.2 Air Circulation Ratio — Air circulation ratio is defined as the ratio of the volume of air per hour passed by the fans, to the volume of the empty chamber. It varies according to the period of refrigeration of the produce or the period during which the temperature is maintained.

4.2 Air Change

4.2.1 Purpose — Plant produce, especially fruits, emit respiratory carbon dioxide, ethylene (which accelerates the ripening of certain fruits from 3°C and has a considerable effect above 7°C), and volatile substances of which some are thought to be responsible for the disease of scald.

To avoid the harmful accumulation of these substances it is necessary to change the atmosphere of the cold store, particularly during the first days of the cooling period, in the course of which the produce has a high metabolic activity, and also in the case of ripening fruits during the final weeks of storage since they emit large quantities of volatile substances when they reach full maturity.

4.2.2 Rate of Air Change — The rate of air change is the ratio of the volume of outside air introduced into the refrigerated enclosure in 1 hour, to the volume of the empty enclosure. For fruit, the rate and frequency of air change depend on the species and varieties, the loading of the store and the degree of development of the fruit.

For vegetables, the need of air change and the rate depend on the species (for example, it is necessary for peas and not for salad materials).

4.3 Measurement of Air Circulation

4.3.1 Principles of Measurement of the Flow and Circulation of Air — Whether circulation or change of the air is in question, two factors have to be considered:

- a) Flow of air introduced (rate of air change) or circulated (air circulation ratio) in a given time; and
- b) Uniformity of the distribution of fresh air or of the circulated air. It may be necessary to take into account the effect of recirculation.

Measurement of the air-circulation ratio should be carried out whenever possible at the exit from, or the inlet to, the evaporators.

Measurement of rate of air change should be carried out at the point preferably where air is introduced into the store.

Measurement of distribution of air in a refrigerated enclosure is difficult and is not included in current cold storage practice. It can be carried out only within the framework of well defined experimental tests.

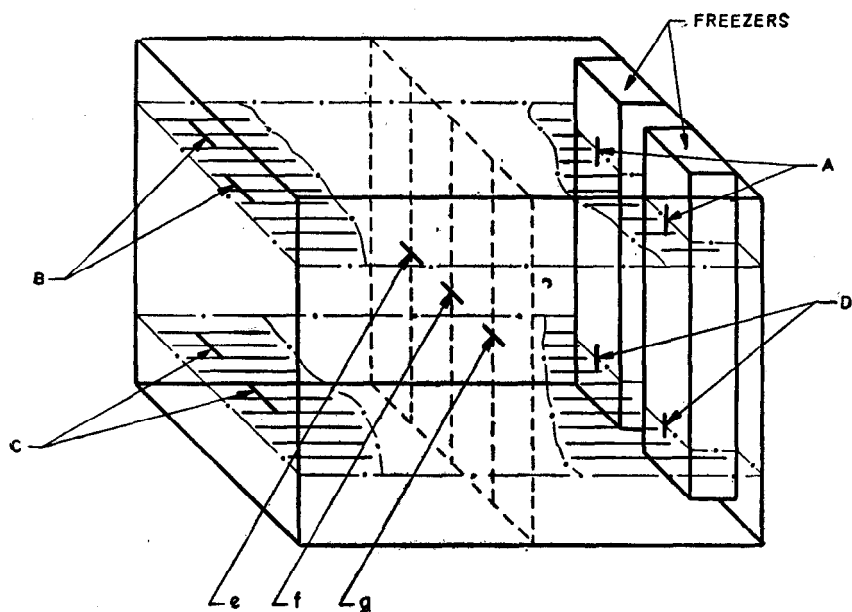
The object of achieving good ventilation is to eliminate irregularities in the air circulation and to obtain the best possible contact between the air and the packages.

4.3.2 Measuring Instruments — Measurement of air speed is carried out:

- a) Either with directional instruments measuring the dynamic pressure of the air for speeds above 2 m/s (Pitot tubes, Prandtl probes, cup-type anemometers, etc); or
- b) With non-directional instruments for speeds below 2 m/s (for example, hot-wire anemometers or any other anemometer).

Measurements of air speed is a delicate operation and it is recommended that reference should be made to specialized texts.

4.3.3 Measurement Points — Some recommended points for the measurement of the air speed (*A, B, C, D*) which give information on the air-circulation in a cold store are shown in Fig. 1.



Points *A* & *B* — Temperature of freezer.
 Points *C* & *D* — Temperature of the return air.
 Points *e*, *f* & *g* — Temperature of the product.

FIG. 1 MEASUREMENT POINTS

(Continued from page 2)

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